1.2 Solar Fuel from the Past

It is a hot, dry summer afternoon deep in a northern forest. It has been weeks without rain when, finally, a thunderstorm rolls in. Lightning strikes the dry grass, igniting a wildfire that eventually engulfs several hundred hectares of forest. The flames are evidence of a violent release of energy.

In previous science courses you learned that **chemical potential energy** is stored in plant material. The original source for almost all energy, including the energy stored in plant material, is the Sun. Nuclear reactions occurring within the Sun's core produce energy that is emitted into space as electromagnetic radiation. A tiny fraction of the **radiant energy** from the Sun strikes Earth, allowing some of it to be absorbed by the complex molecule called chlorophyl, which drives a glucose-making process called photosynthesis. Once the glucose is made, much of it is used to power the plant's growth and reproduction. The remaining glucose within the plant is transformed into other compounds, most notably cellulose—the main component of wood.

All over the world, humans have long harnessed the chemical potential energy of wood for cooking and warmth. The light and heat from wood fires enabled First Peoples to inhabit colder regions of the planet, like the forests of northern Alberta. Heat from fires brings about changes in food as it is cooked, helping make some foods possible to eat and thereby increasing the supply of available food. The vital importance of wood and the ability to release its energy is evident in many stories from Canada's First Nations that describe how fire came to be controlled and used over the past 10 000 years.

Figure D1.11: This diorama—created from stories passed down by elders—at the Royal Alberta Museum shows how First Nations people traditionally dried and smoked fish in the boreal forest of northern Alberta hundreds of years ago.

- **chemical potential energy:** the energy present within the chemical bonds of a substance
- **radiant energy:** the energy of electromagnetic waves

In developing countries, like Kenya, wood is still the least expensive and most accessible form of energy. Wood is the standard fuel for cooking. Most of the wood fuel consists of dead trees and fallen branches collected from fields or from roadsides. Collecting the fuel wood is exhausting work that can consume hours of every day. Since the wood is often burned in an open pit or in a poor-quality stove, incomplete combustion occurs, releasing CO(g), polycyclic aromatic hydrocarbons (PAHs), particulate matter, and other pollutants into the cooking area.

Figure D1.12: A woman in Kenya stands outside her hut beside a pile of firewood.

It has been suggested that health and quality of life could improve in developing countries if charcoal were used for cooking instead of firewood. Charcoal is a fuel produced from wood that used to be commonly used in North American barbecues before gas-fueled models became popular. Although charcoal is a more energy-rich fuel than wood, the process to make charcoal produces many harmful emissions.

DID YOU KNOW?

Charcoal is made during the combustion of wood when extra care is taken to reduce oxygen. In many early societies, charcoal was an important fuel and was made by skilled workers.

Science Links

Substances contained within smoke from combustion can cause asthma, respiratory problems, and even cancer. More information about the health effects of substances within smoke appears in Units A and B.

Practice

13. Studies indicate that approximately 1.6 million people worldwide die prematurely from respiratory diseases caused by the pollution from inefficient wood-burning fires. Refer to your work in previous units to describe the health concerns related to the release of CO(g), polycyclic aromatic hydrocarbons (PAHs), and particulate matter into the environment.

From Wood to Coal

Although wood has been used as a fuel by humans since the beginning of recorded history, it has drawbacks. Wood is bulky, for example, which makes it hard to store and transport. Since charcoal is a more compact, cleaner fuel, it represents an improvement. As populations grow and countries industrialize, new fuels may have to be found in order to meet energy demands.

Figure D1.13: A worker stokes the furnace of a steam locomotive with coal.

Coal, a carbon-rich mineral found in Earth's crust, had been used by ancient societies—in particular the Greeks, Romans, and Chinese—but only for minor applications. In the mid-1800s, coal became the preferred fuel in England. Because of its abundant supply and energy richness, coal provided a dependable energy source for industrial processes and transportation, fuelling the Industrial Revolution.

DID YOU KNOW?

Small pieces of coal can be found along the banks of many rivers in Alberta.

Figure D1.14 shows that coal quickly replaced wood as the dominant energy source after the start of the Industrial Revolution. It is this plentiful and powerful fuel that first inspired humans to dream of a world with limitless energy—a dream where coal-powered machines, such as the steam engine, would lead to lives of leisure and prosperity. Today, coal continues to be an important source of energy across the world. Albertans rely on coal to provide many of their basic needs and wants, since coal is used to generate about 70% of Alberta's electricity.

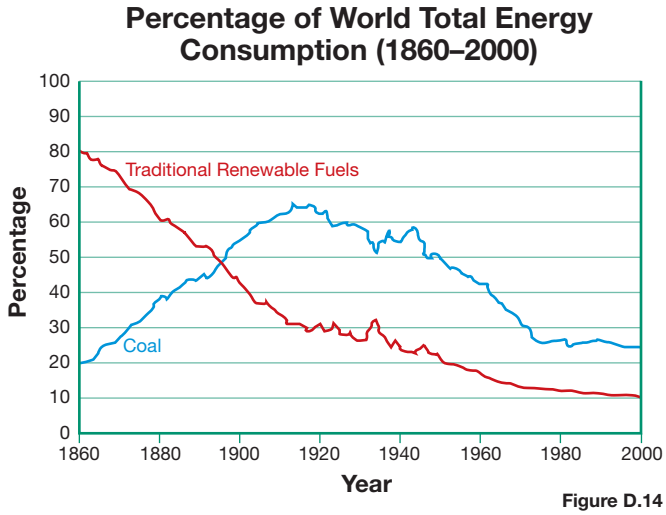


Figure D.14

Practice

Use Figure D1.14 to answer questions 14 and 15.

14. The two fuels shown are coal and traditional renewable fuels. Identify materials that could be classified as traditional renewable fuels.

15. Determine the total percentage of energy consumption provided from coal and traditional renewable fuels in 1950. Account for the value calculated. What other energy sources could be accounting for the difference?

Making Coal

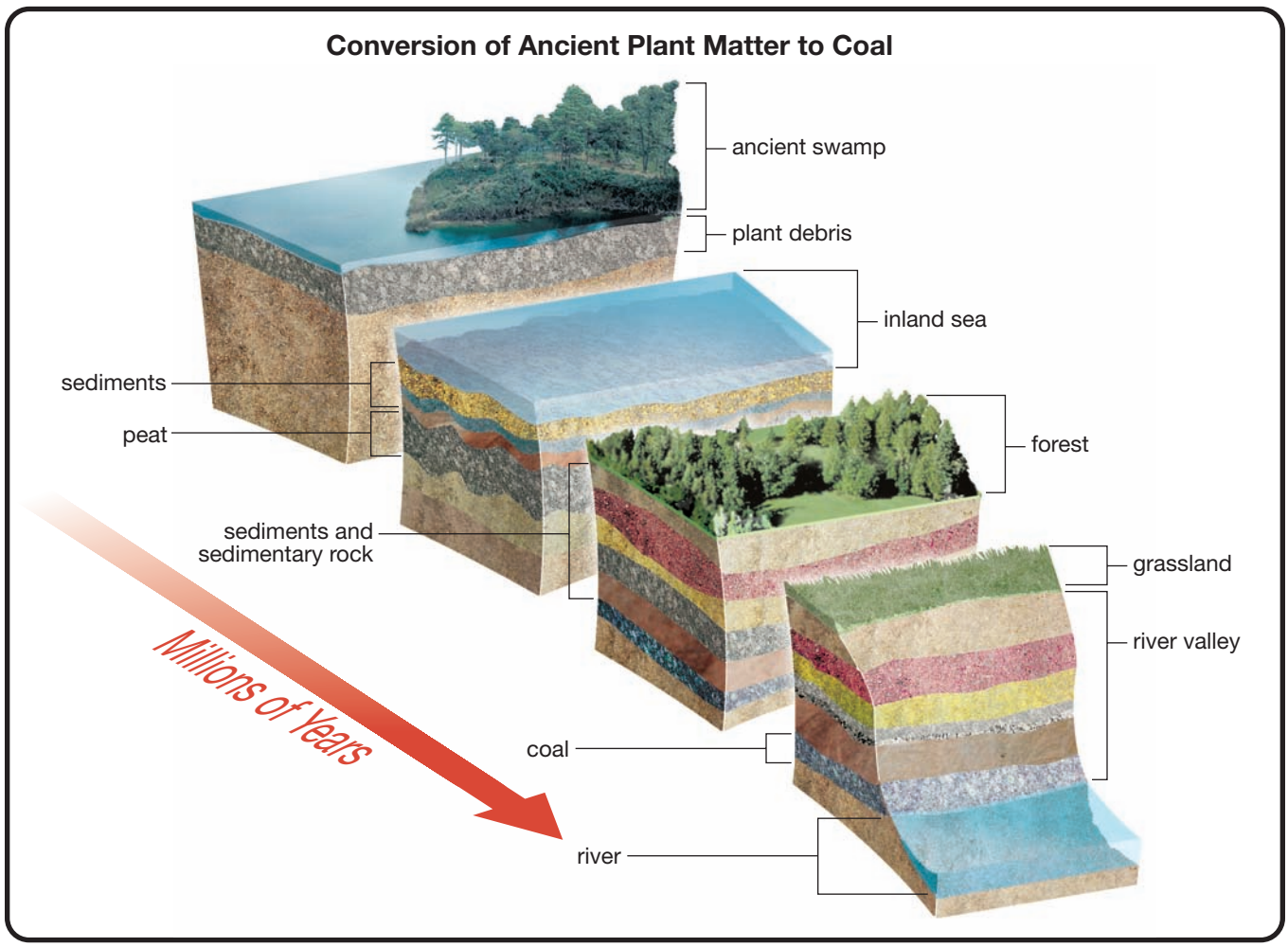


Figure D1.15: It takes millions of years and very specific conditions to make coal. Only a tiny fraction of one percent of the solar energy striking the ecosystem is eventually stored in the chemical bonds of coal.

Specific conditions are required to make coal. In tropical, swampy areas—where moisture and sunlight are abundant—thick layers of plant debris collect in the swamp over time. This layer, called peat, begins to decompose while submerged under water (in conditions without much oxygen). As more layers of plant debris and other sediments accumulate, the peat is compressed, beginning the process of its transformation into coal. The transformation of peat into coal requires millions of years and the pressure of many more layers of sediment. Since coal is derived from the remains of prehistoric life, coal is referred to as a **fossil fuel**.

fossil fuel: a hydrocarbon deposit (e.g., petroleum, coal, and natural gas) derived from plants and animals that lived millions of years ago that is used for fuel

Figure D1.16: Structures of plant parts are often visible on the surface of coal. Parts of a plant's stem are visible as vertical lines in this photograph.

More recent geological events—such as the retreat of the glacial ice sheets that once covered Alberta—removed some of the top layers of sediment that helped compress the coal. The massive runoff from the continental glaciers carved deep river valleys in the Alberta landscape. Events like this exposed coal seams close to the surface, making them accessible for mining.

Lots of Coal

Figure D1.17: A tipple, like this one seen at an abandoned coal mine near Drumheller, Alberta, is used to clean, screen, size, and load coal into rail cars.

Figure D1.18: Many of the coal mines currently in operation in Alberta are open-pit mines, where the topsoil is removed to allow the coal to be loaded into large trucks.

Coal has been mined in Alberta since the early 1900s. Towns like Drumheller, Bellevue, Hillcrest, and Frank have museums where you can view the original buildings and equipment used. Today, coal mining is still a vibrant industry in Alberta and around the world.

In Alberta, surface mining is primarily used to extract coal. Surface mining involves the removal of layers of earth above the coal deposit. The coal seam lying beneath appears like a black carpet and is removed using large mechanical shovels and trucks. Although the cost of machinery to conduct surface mining is high, coal is a relatively inexpensive fuel to obtain using surface-mining techniques. Coal reserves in Alberta that are accessible using surface-mining techniques are estimated to be 620 billion tonnes.

DID YOU KNOW?

When exposed to oxygen, coal begins to decompose, releasing heat. Coal stored outside power plants must be covered with dirt to prevent spontaneous combustion.

In Alberta, areas where coal and other natural resources have been extracted must undergo **reclamation**. Provincial regulations require mining companies to restore land to a condition similar to what existed prior to mining. Areas that have undergone surface mining in Alberta have been restored to make farmland or to blend with the neighbouring natural habitat.

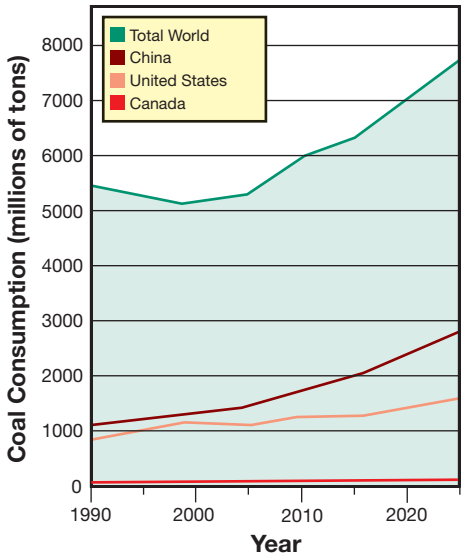
reclamation: restoring an area to its original form or some other usable form

Figure D1.19: Reclamation of the Egg Lake Mine, near Legal, has restored the local ecosystem.

Coal Use on the Rise Around the World

Coal use has increased worldwide and is projected to increase dramatically in the near future. For emerging countries with extensive coal reserves, like China, the availability of coal and the ease by which it can be turned into energy are contributing to the increased use of this energy source. Even in more developed countries, the relatively low cost of coal mining makes it an economical energy source.

Projected Coal Use



DID YOU KNOW?

Coal is the largest commodity carried by Canadian railways.

Practice

16. Peat forms at an average rate of 5.0×10^{-4} m/a (metres per year). It takes 10 m of peat to make 1 m of coal.

- **a.** Calculate the time it took to produce the peat required to make a 5-m thick layer of coal. (**Hint:** Think of this question as a speed problem, $v = \frac{d}{t}$.)
- **b.** Does your answer to question 16.a. account for the total time it would take to make the 5-m thick coal layer? Explain.
- **c.** According to the evidence and the answers to the previous questions, should coal be classified as a renewable or non-renewable resource?

17. Energy density—the energy available per kilogram of combusted fuel—is often used to compare fuels. The following table compares the energy density of bituminous coal (the type found in Alberta), wood, and charcoal.

ENERGY DENSITIES OF SOME FUELS

Fuel	Energy Density (MJ/kg)
coal (bituminous)	23.9
wood	13.5
charcoal	29.0

- **a.** Identify the fuel with the highest energy density.
- **b.** State reasons why the use of charcoal as a fuel is restricted.
- **c.** Explain the benefit of comparing fuels based on energy density.
- **d.** Is it possible to determine the energy density of liquid fuels?

Petroleum—Today's Dominant Fuel

In the 1950s, due mostly to the impact of the automobile on society, **petroleum** became the world's primary fuel. In the 10 years following World War I (1918 to 1928), the number of automobiles in the United States and Canada increased by a factor of 4. By the beginning of World War II, most families in Canada and the United States owned a car or truck. Today, petroleum is by far the world's top energy source. Petroleum is a mixture of hydrocarbons—each a rich energy source but suited for different purposes. One of the early uses for petroleum was to make kerosene for lamps.

petroleum: liquid hydrocarbons formed over millions of years from the remains of ancient microscopic marine organisms

DID YOU KNOW?

Gasoline, the mixture of hydrocarbons consisting of seven to ten carbon-atom chains, is one of the by-products of making kerosene. In the mid-1800s there was no use for gasoline, so it was discarded.

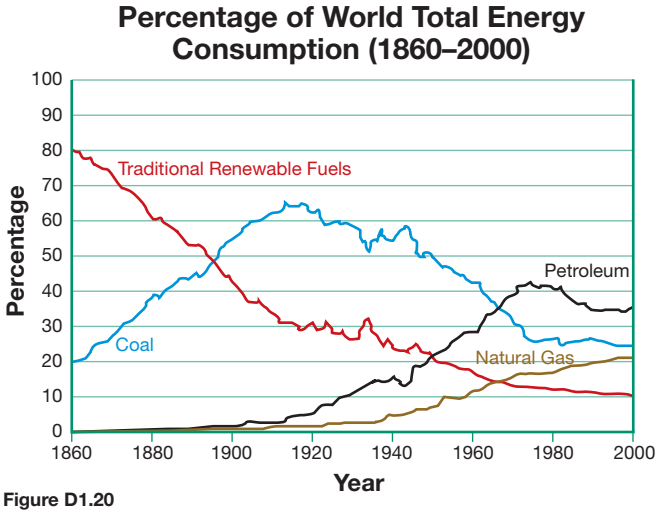


Figure D1.20

Practice

18. Use Figure D1.20 to answer questions 18.a. to 18.d.

- **a.** In the year 2000, identify the two fuels, other than coal, used the most.
- **b.** Describe the trend in the use of coal from 1860 to 1920.
- **c.** Identify the fuels that began to replace coal as an energy source from 1920 to 1950. Suggest reasons why coal was replaced.
- **d.** Describe the trend in energy supplied by coal from 1975 to 2000. Suggest a reason for this trend.

Figure D1.21: In the 1950s, parked cars lined Edmonton's Jasper Avenue, signifying society's reliance on the automobile and the importance of petroleum.

Making Petroleum

Petroleum, like coal, requires special conditions and a great deal of time to form. The shallow tropical seas that existed 360 million years ago over what we now call Alberta contained coral reefs that covered many hundreds of square kilometres. Photosynthetic plants within the reef ecosystem trapped and stored solar energy. Over millions of years, the pressure from hundreds of metres of sediments that covered these reefs, and just the right amount of heat, converted the molecules containing carbon from these organisms into petroleum.

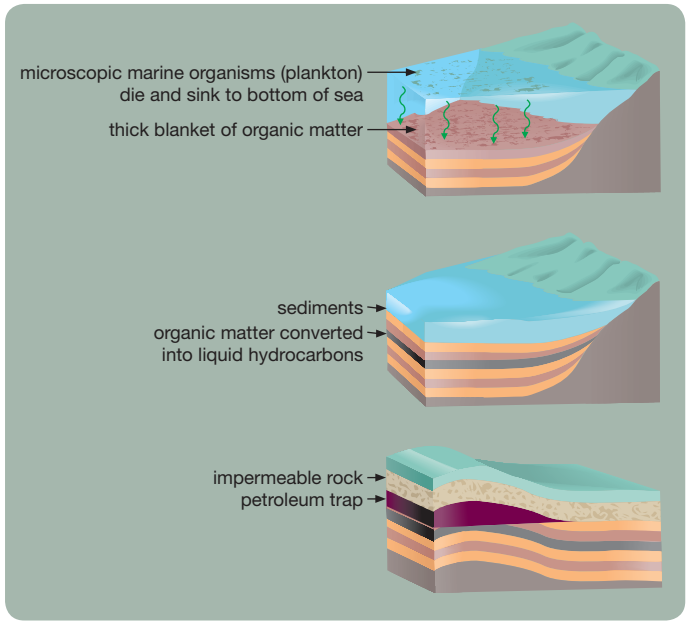


Figure D1.22: Many geologists believe petroleum formed from plankton over millions of years.

The buckling of rock layers, caused by movement of Earth's tectonic plates, allows petroleum to seep from within the rocks and then to form larger pools. The movement of water through rock layers forces the less dense petroleum upward, where it becomes trapped in dome-shaped formations that contain today's petroleum reservoirs. Since the discovery of petroleum near Leduc in 1947, Alberta has enjoyed a lucrative industry to extract and process petroleum.

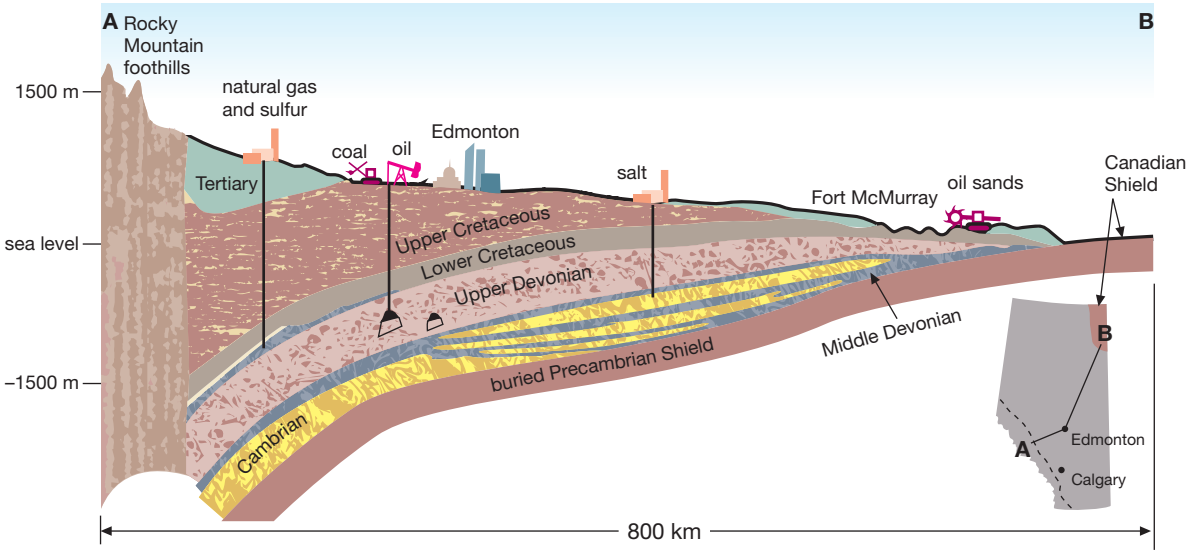
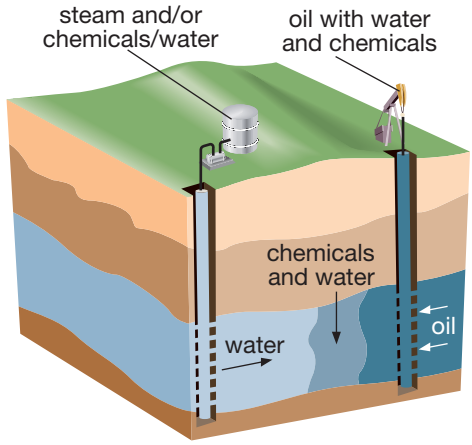


Figure D1.23: A cross section of Alberta shows major rock layers and some of the mineral resources they contain.

Enhanced Oil-Recovery Process

Over half of the petroleum within a deposit is difficult to remove. Enhanced oil-recovery techniques involve the pumping of water, chemicals, or gases into the rock layers that surround a petroleum reservoir to force petroleum into the well for extraction.



Practice

19. A great deal of concern exists over the use of water from lakes and rivers for enhanced oil recovery. Use the Internet to prepare a list of some of the concerns expressed over the use of water for enhanced oil recovery.

The Athabasca Oil Sands

Alberta's Athabasca oil sands may be one of the world's largest petroleum reserves; however, the petroleum is relatively difficult to extract. Rather than being deposited in a trap, as with conventional petroleum reservoirs, the petroleum in oil sand is stuck to individual grains of sand.

The production of petroleum from oil sand is an expensive endeavor. Oil sand can be removed using surface mining techniques similar to those used in open-pit coal mines. Approximately two tonnes of earth is removed to produce one barrel of petroleum. After extraction, the oil sand is washed with water and solvents. Two main products from washing include bitumen (a black tar) and tailings (a wet, sandy mixture). Thermal energy is required to break the hydrocarbon molecules in bitumen into smaller molecules suitable for use in products like diesel fuel. Additional production costs include reclamation of the land, cleaning of the tailings from the mine, and the treatment of water use in the oil sand extraction process.

Figure D1.24: The Athabasca oil sands span 77 000 km^2 of land and contain up to 18% petroleum.

DID YOU KNOW?

In 2006, the average cost to produce petroleum from oil sand was just over $27 per barrel.

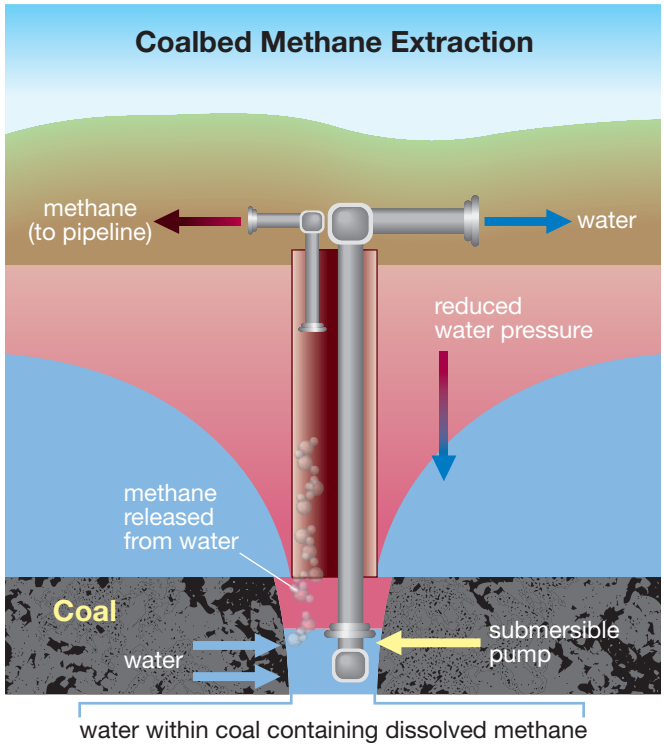
Natural Gas (Methane)

Natural gas is a mixture of hydrocarbons primarily composed of methane and, to a lesser extent, ethane, propane, and butane. Natural gas forms in much the same way as crude petroleum. The key factor that determines whether the ancient organic material will become natural gas instead of petroleum is temperature—natural gas requires more heat as it forms. Natural gas is often extracted by drilling deep underground. It is then transported by networks of pipes to individual buildings, like homes and schools. It is natural gas that most likely fuels a home's furnace and water heater and, possibly, kitchen stove; it likely fuels any Bunsen burner that may be in a school's science laboratory. Natural gas is the primary fuel used for heating in industrial processes, like processing bitumen from oil sands. It is also used as an essential ingredient for thousands of industrial and consumer products.

Coalbed Methane and Methane Hydrate

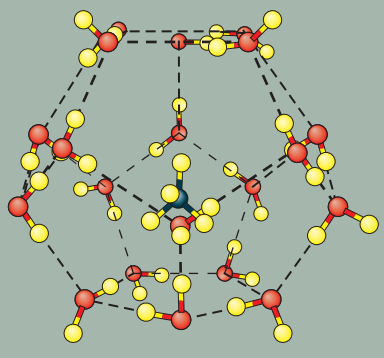
Concern about the limited supply of conventional hydrocarbon resources has created interest in new sources of hydrocarbons, namely methane. As you learned earlier, methane, $CH_4(g)$, is the major component of natural gas. Although methane is the smallest hydrocarbon molecule, it has a very high energy density—over three times that of wood. Given its energy richness and the ease by which it can be used, reserves of methane are highly sought after.

Recently, attention has been focused on a new source of methane—coalbed methane. Coal, being a porous material, often contains water. During the processes that make coal, methane is also produced and becomes trapped within the layers of coal, dissolving into the water within the coal bed. Dissolved methane can be removed from the coal bed by pumping the water within the coal formation to the surface. As the water nears the surface, the reduction in pressure causes the methane to vapourize and separate from the water. Unlike enhanced oil recovery, water is not needed to collect coalbed methane; but the water collected by this process tends to contain high concentrations of dissolved minerals, making it unsuitable for irrigation or other uses.



The development of coalbed methane projects in Alberta is connected to water issues. There are concerns that if you draw water from coalbeds, there will be an impact on water wells used by farmers. Also, the fate of water drawn from a coal bed is not certain. Simple solutions like pumping it back underground where it could contaminate other water sources may not be suitable.

Methane can also be found within ice as methane hydrate. In deeper, high pressure regions of Earth's oceans, where water temperatures are near freezing, methane leaks from geological sediments and becomes trapped within ice.



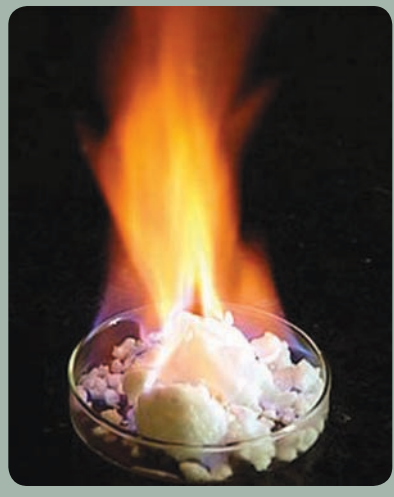


Figure D1.25: Methane hydrate (right) is methane frozen within water. The methane molecule (above) is surrounded by water molecules to form methane hydrate.

Fossil Fuels—Non-Renewable Resources

Coal, petroleum, and natural gas are all fossil fuels. As the name implies, they are extremely old and take a very long time to form. Fossil fuels are **non-renewable**. This means that once the world's supplies of coal, petroleum, and natural gas are consumed, they cannot be replaced. Fossil fuels are often called **hydrocarbons** because they contain mostly hydrogen and carbon.

Many scientists believe that over half of the world's petroleum supplies have already been used up; but, as shown in Figure D1.26, the world's petroleum production is increasing. Estimates of how long coal, petroleum, and natural gas reserves will last vary significantly. Differences between estimates are often due to the research methods selected to collect data or the interpretation of the data.

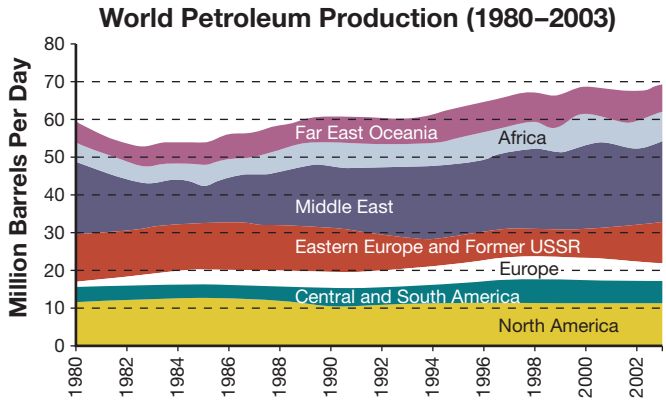


Figure D1.26

Whenever you hear information or conclusions from a study, you must consider the source of the information and any possible **bias**. Research—since it is an activity conducted by humans—needs to be evaluated for any potential bias. For example, a team of researchers sponsored by a large multinational oil company could have a different set of biases than a team sponsored by an environmental organization.

- **non-renewable:** can only be used once within the scope of human timescales
- **hydrocarbon:** an organic compound containing only carbon and hydrogen atoms
- **bias:** a preference for one particular point of view that interferes with neutral or objective decision making

Utilizing Technology

How Long Will Fossil Fuels Last?

Background Information

Information or opinions must be considered for any possible bias. In this activity you will consider the bias of sources as you collect estimates regarding the length of time that the world's supplies of fossil fuels will last.

Purpose

You will find three estimates of how long each type of fossil fuel will last, and you will evaluate the resources from which the information is obtained.

Procedure

step 1: Obtain the document "Researching the Future of Fossil Fuels" from the Science 30 Textbook CD.

step 2: Use the Internet to complete the "Estimates of How Long Conventional Fossil Fuels Will Last" table on page 1 of the handout.

step 3: Use the Internet to complete the "Newly Developed Sources of Fossil Fuel Energy" table on page 2 of the handout.

Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting

Analysis

1. In step 2, you likely found that predictions concerning the availability of fossil fuels in the years to come varied. This indicates that there is some uncertainty surrounding this issue. Should this uncertainty prevent industry, governments, and consumers from investing time and money in research into alternatives to fossil fuels?
2. Identify at least one action you think should be taken by each of the following groups to address the likelihood of the world's petroleum and natural gas supplies running out in the next several decades.
   - citizens
   - government
   - industry
3. Suppose new sources of hydrocarbon fuels, such as coalbed methane and methane hydrate, could meet the world's energy demand for several centuries. Suggest reasons why efforts should still be made to find alternative fuels.

1.2 Summary

Fossil fuels—such as coal, petroleum, and natural gas—are important energy sources. All fossil fuels are finite and non-renewable. Given the present rates of consumption, estimates suggest that supplies of petroleum and natural gas will likely be depleted within decades. Estimates for coal suggest it will be depleted within centuries. In the lessons that follow, you will examine alternative energy sources to fossil fuels and the contributions these alternative energy sources can make toward meeting projected energy demands.

1.2 Questions

Knowledge

1. List the three main fossil fuels used today. Of these fuels, identify which is consumed globally at the highest rate.
2. Identify the energy source used to generate most of Alberta's electricity.
3. Describe how burning fossil fuels results in the release of solar energy.
4. Define the following terms.
   - **a.** fossil fuel
   - **b.** solar energy
   - **c.** hydrocarbon
   - **d.** non-renewable
   - **e.** chemical potential energy
5. Identify the world's main energy source prior to the widespread use of coal in the 1800s.

Applying Concepts

6. Determine whether the energy stored in fossil fuels is best classified as kinetic energy or chemical potential energy. Explain your reasoning.
7. Imagine that fossil fuels are no longer available and there is no replacement available. List the activities in your life that would no longer be possible or would have to change.

Use the following information to answer questions 8 to 10.

Many countries, like Japan and the United States, rely heavily on petroleum imports, which can be threatened by political instability. This was the case in 1973 when the members of OPEC (Organization of the Petroleum Exporting Countries) would not export petroleum to the United States. This embargo on the shipment of petroleum had many effects on the United States's economy. At the height of the crisis, gasoline prices quadrupled. This massive petroleum shortage motivated the automobile industry to develop more fuel-efficient engines.

8. As petroleum and natural gas become more difficult to extract in the coming decades, describe the likely effect on the price of gasoline.
9. Identify the main areas of the economy that would be affected by a shortage of petroleum and natural gas.
10. Explain why a shortage of petroleum might lead to new developments in automotive technology.